

ential mode. Furthermore, the illustrated methodology used for providing LF will be appreciated as being exemplary of the type of methodology that could be implemented as it will be appreciated that other techniques such as for example, low pass filters or LF match-box components connecting LF power to the HF lines, could be used to couple LF power into the system.

[0023] The generators or supplies can be operated in either VHF or RF modes, with the difference being that in VHF mode the high frequency will couple inductively whereas in RF mode, it will be coupled capacitively. The ability to change frequency enables one to control the transfer from an inductive discharge to a capacitive discharge, so that one can go from high to low frequencies and vice versa without resultant non-uniform etch (or whatever surface treatment is being provided using the plasma treatment) profiles resulting on the workpiece, as would happen if a single electrode were utilised as in the prior art arrangements. Although the actual frequency at which the inductive discharge becomes predominant is not exact, it is thought that at frequencies of about 500 MHz, that the plasma discharge is predominately inductively based.

[0024] In a modification to that described heretofore, the present invention also provides for the HF source to operate in a switch mode as opposed to a sinusoidal operation. Such a switch mode operation is advantageous in that it is possible to alter the slew-rate of the switch region so as to yield an "effective frequency" which will determine amount of inductive coupling. The length of time the reactive element is left in the high voltage state would control the ion bombardment energy. Switch mode generators are very well known in the general electronics field with well defined characteristics and components. The ability to use such a switch mode generator provides for a reduction in cost of the plasma source—switch mode generators are cheaper than the equivalent sinusoidal based generator. By controlling the slew rate one is able to move easily from the RF range to Ultra High Frequencies (UHF) thereby providing the possibility to tune the process chemistry and/or the electron temperature,  $T_e$ .

[0025] Heretofore, the invention has been described with reference to a plasma source configured to operate with a planar workpiece, where the electrodes making up the reactive impedance element and the reference electrodes are substantially parallel to each other and to the workpiece. Such arrangements are advantageous and useful for application in the semiconductor environment where a planar wafer is provided for etching. However it is known that plasma sources can also be used in other applications where it is desired to process a non-planar substrate, for example a roll of film in a textile screen printing application. FIG. 3 shows in schematic form how the present invention can be configured for use in such an arrangement 300 where a roll of film 305 is originally provided on a reel 310. The film is unwound from the initial reel 310 on an unwind station 315, passes through the plasma source 105 where it is processed and is re-wound on a rewind station 320. The plasma source of the present invention is suitable for processing such large dimension surfaces because the multiple electrodes that make up the reactive element enable the provision of uniform plasma over an extended area. The arrangement of the present invention allows for the provision of higher frequency sources to be used and therefore the speed of the film

through the plasma source can be increased. These higher frequencies do not lead to a detracting in the quality of the plasma as the multiple electrodes of the reactive element provide for higher density application without detracting from the uniformity of the applied plasma. It will be appreciated that such an arrangement may also be modified for plasma screens, LCD displays, industrial coating on metal/glass, and the like where simultaneous processing of large areas is required. Although the LF supply shown in this embodiment is coupled to the substrate plate it will be understood that in a manner similar to that described with reference to FIG. 2 that one could also have a low frequency feed through the upper reactive elements.

[0026] Certain applications may require the use of a curved processing area. The present invention provides for such processing in one of two ways. In the first, in a manner similar to that described with reference to FIG. 3, the invention utilises a substantially planar arrangement of reactive elements to process a curved workpiece. FIG. 4 shows an alternative arrangement in accordance with the teachings of the present invention, where the source could be applied to non-planar plasma volumes. In this example it may be advantageous to provide an electrode configuration that can be configured in a non-planar configuration, and this example uses a hexagonal close pack configuration 400 including a plurality of individual hexagonally dimensioned electrodes 405. In this example, a 3 phase drive mechanism is used as opposed to the direct push pull operation of the configuration of FIGS. 1 to 3, and each of the individual electrodes is coupled to a respective one of the three sources (identified by the labelling 1, 2, 3 respectively). As with the embodiment of the previous Figures, no two adjacent electrodes are in phase with one another—see FIG. 5 for an example of the output configuration for each of the sources. To assist in current imbalance a tri-filar transformer may be used which is advantageous in that it allows for the provision of a low voltage above the substrate and an equalisation of the currents. In other circumstance, it will be appreciated that certain applications where it is useful to drive a net current and therefore a net voltage into the reference electrode may find it advantageous to have a current imbalance. It will be further appreciated that the examples of two and three phase sources are exemplary of the type of frequency generator that could be used with the reactive elements of the present invention and that certain other applications may require sources capable of providing a higher order phase supply.

[0027] Although the plasma source of the present invention may be used with known gas distribution feeds such as a shower effect electrode with radial gas flow and pumping on the perimeter of the plasma volume, the present invention also provides in certain embodiments sources that utilise a gas distribution feed that enables the removal of gas away from the lower reference electrode. FIG. 6 shows a portion of such a source where two adjacent electrodes that make up the reactive element are illustrated. The electrodes are mounted below a gas feed chamber 600, and the gas that is within this chamber may be introduced firstly to a feed chamber 630 through an entrance conduit 620 and then into the plasma excitation region 110 through a plurality of apertures 605 provided in the electrodes of the type that will be known to those skilled in the art from existing shower-head technology. Once the gas has entered into the excitation region 110 it then flows towards a ground plate 610 provid-